

# PARALLEL AND SELECTIVE GROWTH METHOD OF CARBON NANOTUBE ON THE SUBSTRATES FOR ELECTRONIC-SPINTRONIC DEVICE APPLICATIONS

## BACKGROUND OF THE INVENTION

### 1. Field of the Invention

The present invention relates to a parallel and selective growth method of carbon nanotubes (CNT), and particularly, to a parallel and selective growth method of carbon nanotubes for electronic-spintronic device applications which grows the carbon nanotubes directly on a wanted position.

### 2. Description of the Background Art

Recently, a new technique is required because miniaturization and integration of an element are made more rapidly and continually than before. At present, the smallest line width made in the manufactured silicon is about  $0.17\mu\text{m}$ , and it may be developed to be  $0.1\mu\text{m}$  of line width. However, it is difficult to develop a silicon having a line width smaller than  $0.1\mu\text{m}$  using a lithography art at present.

On the other hand, a carbon nanotube (hereinafter, referred to as CNT) found by Iijima of Japan is a new material of next generation which draws attention because its unique electric and mechanic characteristics. In forming a terabit molecule device of nano size, to make the line width less than  $0.1\mu\text{m}$  without using the conventional lithography art is possible using a self-assembly technique or using selective growth of the CNT having a diameter of  $1\text{nm}\sim 10\text{nm}$  and moving by one-dimensional proton beam or wiring technique.

If the lithography technique is used, it has advantages for integration because of high ordering and reproducibility, however, it is subordinated to the development of the lithography technique. And the self-assembly technique uses a mechanism in which the materials are formed as nano size, and therefore it is difficult to reproduce and standardize, and it has disadvantages for integrated molecule device application of high yield.

On the basis of results of researches for the CNT, the nanotube may be form a foundation of an electronic engineering. The CNT is chemically inert comparing to another materials which are now studied, and is hard for pierls distortion, and is physically strong and elastic.

Figures 1a and 1b are drawings showing examples of conventional CNT growth.

As shown in Figure 1a, it is difficult to standardize the CNT because a diameter and a length are grown irregularly due to the characteristics in synthesis process, and therefore an individual device is fabricated such that an individual CNT is manipulated and arrayed using a tip of STM (Scanning Tunneling Microscope) or of AFM (Atomic Force Microscope). However, in order to fabricate integrated nano-devices, a countless of CNTs are should be moved on wanted positions and adhered on the positions with an accuracy of atomic scale on a substrate.

Also, as shown in Figure 1b, the CNT powder is refined a couple of times and dropped on a board on which a pattern is formed using a spin coating or a spit. After that, the CNT on unwanted position is removed using a needle of STM or of AFM, or the CNT decentralized in a solution is picked and arrayed on the board, however it is nearly impossible to fabricate an integrated device in this method.

On the other hand, in most compounding field, a technique which growing vertically for the board are now being developed in order to apply to display. However, even in a CNT film which is grown vertically and well arrayed, lengths of respective CNT are different from each other and intervals between the CNT are unequal, and therefore it is difficult to fabricate an electric device using the CNT in as-grown state.

Therefore, at present, a technique, in which the synthesized nanotubes are collected and refined a couple of times, and after that nanotubes having same diameter and length are separated, is developed in priority. And most researches in application devices fields are searching for reconstructing the grown CNT through the complex refine processes. Therefore, this inefficient fabricating processes are not able to be applied to practical fields such as highly integrated nanoelectronic devices or spintronic devices.

## SUMMARY OF THE INVENTION

Therefore, an object of the present invention is to provide a parallel and selective growth method of semiconductive and conductive carbon nanotube for developing an electronic device of high integration by growing in horizontal direction on wanted position, between patterns, and on a wanted clearance with in-situ, and to provide an example of the application device.

To achieve the object of the present invention, as embodied and broadly described herein, there is provided a parallel and selective growth method of carbon nanotube for electronic and spintronic device applications comprising the steps of: forming an insulating film on a board; forming a fine pattern of catalyst

metallic layer including a contact electrode pad on the insulating film; especially, forming a barrier layer for vertical growth on upper part of the catalyst metallic layer; and directly growing the carbon nanotube between the catalyst patterns.

The foregoing and other objects, features, aspects and advantages of the present invention will become more apparent from the following detailed description of the present invention when taken in conjunction with the accompanying drawings.

#### BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings, which are included to provide a further understanding of the invention and are incorporated in and constitute a part of this specification, illustrate embodiments of the invention and together with the description serve to explain the principles of the invention.

In the drawings:

Figures 1a and 1b are drawings showing a conventional growth method of carbon nanotube;

Figures 2a through 2c are cross-sectional views showing parallel and selective growth method of carbon nanotube according to an embodiment of the present invention; and

Figures 3a and 3b are drawings showing selective parallel growth of the carbon nanotube according to the embodiment of the present invention.

#### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Reference will now be made in detail to the preferred embodiments of the present invention, examples of which are illustrated in the accompanying drawings.

The insulating film uses a thermal oxidation film made by thermal oxidation and CVD (Chemical Vapor Deposition) methods in an electric furnace of 1100°C, a  $Al_2O_3$  thin film made by a sputter method, a  $SiO_2/Si_3N_4$  nitrogen film, or a layered structure of these.

It is desirable that the insulating film is formed to having a thickness of 50~1500nm.

It is desirable that the catalyst metal is Ni, Ni/Ti (or Nb), Co, Co/Ti (or Nb), Fe, Fe/Ti (or Nb), (Ni/Co)n, (Co/Ni)n, (Co/Ni/Co)n, (Ni/Co/Ci)n ( $n=1, 2, 3, \dots$ ), and Co/Mg.

And it is desirable that the barrier layer for vertical growing uses an oxide film, a nitrogen film, or a layered structure of these two, and  $SiO_2, Si_3N_4, SiO_2-Si_3N_4, Al_2O_3$ , etc. In some cases, the growth wall layer may use metals, that is Ti, W, Nb, V, Au, or may use a compound metal of these metals. The metals are formed on the catalyst metal, or on upper part of the catalyst metal, and therefore block the vertical growth, but contribute to horizontal or side surface growth. The thickness of the oxide film or of the nitrogen film is varied within a range of 20~30nm in order to make a top gate device later. The metal or compound metal wall can be used as an electrode later.

In addition, it is desirable that the catalyst metal has a purity higher than 3N, and is formed to have 100~400nm thickness in a temperature range of normal temperature~150°C.

The CNT(Carbon Nano Tube) growth is made in  $C_2H_2$  (or  $C_2H_4$ )/ $N_2$ (He, Ar),  $H_2$  or  $NH_3$  gas atmosphere, in gas pressure 10~500Torr, and

for 10~3000 seconds.  $H_2$  or  $NH_3$  is included as a gas for carrying, and the mixture ratio is  $C_2H_2$  (or  $C_2H_4$ ):  $H_2 = 1: 1\sim 10$ .

And it is desirable that the CNT growth is made using a thermochemistry gas phase deposition process (or a plasma process), and the temperature of the processing room is within a range of 500~900°C (error range are  $\pm 10^\circ\text{C}$  at both ends).

The CNT growth uses an amorphous carbon thin film and graphite as an self-catalyst function, and growth speed is 100nm/m.

And it is desirable that the spacing between catalyst metal patterns is 50nm~10 $\mu\text{m}$ .

In addition, it is desirable that the diameter of the CNT is 1~50nm.

A normal metal, a superconductive metal, and a magnetic metal may be used as the contact electrode as well as growth barrier layer.

Hereinafter, the parallel and selective growth method of the carbon nanotube for electronic-spintronic device applications according to the present invention will be described in more detail as follows.

Figures 2a through 2c are cross-sectional view showing the parallel and selective growth method of carbon nanotube according to an embodiment of the present invention, and Figures 3a and 3b are drawings showing the parallel and selective growth of the carbon nanotube according to the embodiment of the present invention.

As shown in Figure 2a, a gate insulating film 101 is formed on a board 100 using a wet oxidation process in an electric furnace of 1100°C. At that time, the thickness of the gate insulating film 101 is 500nm, and  $Al_2O_3$  is laminated on the insulating film as 10~50nm thickness.

In addition, catalyst patterns are formed on the gate insulating film 101 with about 30nm~10μm intervals between them using an usual electron-beam litho method which forming catalyst patterns.

And as shown in Figure 2b, one or plural catalyst metal layers 103 are formed using an electron-beam deposition or using a sputter deposition. At that time, a thickness of the catalyst metal layer is 10~400nm in case that one layer is formed. In addition, in case that a Ti film as a buffer layer for restraining granulation of the catalyst layer which may happens during the growth of the CNT, the thickness of the catalyst metal layer may be formed to be thin. Also, the thickness of the baffle layer for that of the catalyst metal layer 103 is formed as larger than a ratio of 1:1.

In addition, a spacing between the catalyst layers 103 is about 50nm~10μm, and as a material of the catalyst metal layer 103, Ni, Ni/Ti (or Nb), Co, Co/Ti (or Nb), Fe, Fe/Ti (or Nb), (Ni/Co)<sub>n</sub>, (Co/Ni)<sub>n</sub>, (Co/Ni/Co)<sub>n</sub>, (Ni/Co/Ci)<sub>n</sub>(n=1,2,3,...) and Co/MgO are can be used.

Also, as a material of the contact electrode pad 104, a normal metal, a superconductive metal, and a magnetic metal can be used, whereby various electronic- spintronic functions may be added.

In addition, a test piece, on which catalyst metal source having a purity higher than 3N is installed, is formed to have 30nm~400nm of thickness in the temperature range of normal~150°C.

In addition, as a growth barrier layer (disturbance layer) for disturb the vertical growth upward the catalyst metal, an oxide or nitrogen, or, laminated/ mixture structure of these two can be used, and also  $SiO_2$ ,  $Si_3N_4$ ,  $SiO_2-Si_3N_4$ ,  $Al_2O_3$  can be formed. Also, metals such as Ti, Pt, W, Nb, V, Au or compound





edge, and the CNT 106 growth is started selectively therefrom.

As shown in Figure 3a, the contrast is very high on the edge of the pattern, and that position designates the part of the catalyst metal layer 103 having thinner thickness than that of center part.

Also, as shown in Figure 3b, the CNT 106 which is horizontally grown while connecting the electrodes has both ends buried inside the catalyst electrodes which are facing each other, whereby high contact resistance problem which may be generated in CNT-electrode contact can be solved.

Effects of the selective and parallel growth method of carbon nanotube for electronic and spintronic device applications according to the present invention will be described as follows.

The method according to the present invention can be used as an essential and core art in making all electronic and spintronic devices using carbon nanotube, and integrated devices of them, and in a nanowire technique for wiring and connection between devices of nanosize by growing the CNT directly on a wanted position selectively toward horizontal direction (lateral direction).

Also, the both ends of the CNT which is grown horizontally while connecting the electrodes are buried inside the catalyst electrodes which are facing each other, whereby high contact resistance problem which may be generated in CNT-electrode contact can be solved.

As the present invention may be embodied in several forms without departing from the spirit or essential characteristics thereof, it should also be understood that the above-described embodiments are not limited by any of the details of the foregoing description, unless otherwise specified, but rather should be construed broadly within its spirit and scope as defined in the appended claims,

